Found. Phys 13 (1983). pp. 481 – 499.

Nonlocality and the Kochen-Specker Paradox

New Introduction (Salzburg 1983)

Early debates on interpretation of QM — between Einstein & Bohr culminated in 1935 with EPR paper — Bohr declared the winner.

Since the 1960's there has been a great deal of renewed interest in the interpretation of QM.
In particular a number of negative results have been proved, showing what won't work.

Let us begin by asking the question:

What can be said about the values of an observable when the state is not an eigenstate of that observable?

We distinguish 3 sorts of answer.

Slide ⑩

A Sharp unknown value
B unsharp or fuzzy value.
C undefined or meaningless value.

B was shown to involve a version of non-locality (unsharp values could be made sharp 'at a distance') by EPR in 1935.

C is Copenhagen complementarity interpretation — the main difficulty here is to understand clearly what that interpretation really consists in.

A has been shown to involve two difficulties

1) Can we consistently assign values to all observables in all states.

2.) Can we reproduce statistical predictions of QM in all cases.

To 1) the answer is NO according to the Kochen – Specker paradox (1967)

To 2) The answer is NO according to the Bell inequality argument (1964) unless we admit non-locality. (sharp + sharp)

Now many people have discussed how to get round these no-go results.

In my own work I am going to circumvent the K-S paradox but use their argument to substantiate the non-locality difficulty in the face of some at least of the arguments brought against Bell's own proof of non-locality.

* $\mathcal{H}_1 \otimes \mathcal{H}_2$

$\uparrow$

Maximal A abelian $\overline{G}$

$A \otimes 1$ — non-maximal

Kochen-Specker Paradox

Show (13) View A ~~[illegible]~~ + FUNC ⇒ Contradiction

Define ~~[illegible]~~ FUNC

Proof of K-S contradiction   Show (12), (14) (15), (16), (17a).

FUNC enforces relations between values of incompatible magnitudes

Show (13a) Break FUNC by Deockhamization

~~Proof of FUNC.~~

Distinguish A_B, A_C.

But assume $FUNC^\alpha$ $A_B = A_C$ if B, C commute.

Show (13b) Proof of FUNC

Show (14) Define $[A_B]^\phi$ — Ontological Contextuality

Define $[A_B]^\phi(C)$ — Environmental Contextuality

Show (14d) OLOC *

locally maximal observables are not split by ontological contextuality

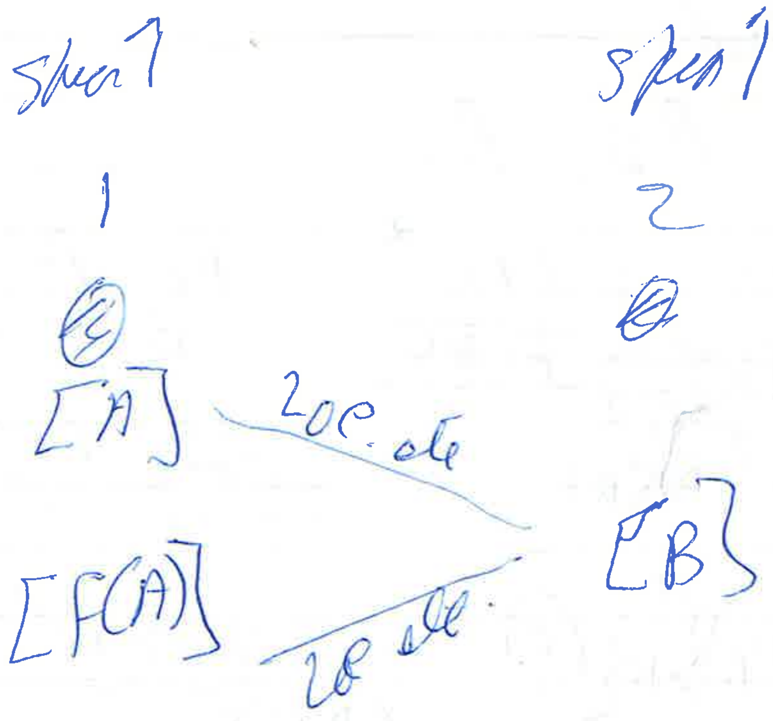
Show (14e) ELOC   as in LOC_3

N.B.(1) ELOC only if locality parallel to OLOC is satisfied.

(2) In terms of measurement results OLOC = ELOC.

* Fine (1974): 'Hidden variables are one thing, hidden assumptions another.'

γ. Sketch Proof


Spin ½
Spin ½
1
2
θ
θ
[A]
[f(A)]
[B]
20e. ole
2e ole

Hence we try to establish a relation between [A] and [f(A)] via the common link with [B] and in particular

$$[f(A)] = f([A])$$

Redhead - Heywood Result *

Show (16)

FUNC* & {VR} + ELOC + OLOC ⇒ Contradiction

{ Defn of VR

Fine Quote on hidden assumptions *

Bell's original proof involved FUNC in form of product rule (to justify SD)

Also Bell Inequality commits us to joint distributions for non-commuting observables

Fine's mistake - Confuses Kolm. joints & von Mises joints

But probability is involved in Bell Inequality approach

Query Can we give purely algebraic proof of non-locality?

Bub (1976) Extension of Maczynski's Theorem (1971)

But Demopoulos et al. show M's theorem can be extended to locally maximal observables (1980)

So OLOC need not be violated

Violation OLOC ontological Holism

Violating ELOC - similar to non-locality in Bell-type proofs

N.B. violating ELOC is only a locality issue if OLOC is assumed.

show 14a Definition of $\left[Q \otimes I\right]^{\phi}_{\{\langle A,B\rangle\}}(D,E)$

show 15 OLOC and ELOC in Symbols

Concluding remarks

Our proof is superior to Bell's in that it makes minimal and transparent use of probability theory (no VR).

But perhaps there is still no way of wriggling out of the non-locality results. This is the approach of Stochastic hidden-variable theories

1). Here measurement results are only ~~and~~ stochastically related to the values of the observables.

This could lead us to give up VR (and FM is abandoned) and in this situation there are well-known difficulties in proving the Bell inequality pointed out by Redhead (Keele Conference 1981) and Hellmann (in Synthese papers)

But if we give up FM can we really talk about measurement at all?

~~With that thought I will throw the paper open to discussion.~~

2) Alternatively if there is FM but stochastic dependence of [Q] on environment there are difficulties in formulating locality principles which require an interpretation of counterfactuals - cf PLCD. But then strict antecedent conditionals can be explained

With these thoughts I will throw the paper open to discussion.